Description

METHOD AND DEVICE FOR DETECTING A DEGREE OF POLLUTION OF AN OPERATIONAL CONVERTER

[0001] The invention relates to a method and a device for detecting a degree of pollution of an operational converter.

[0002] When converters, for example frequency converters, are operated in an environment which is polluted but for which they do not have a corresponding protection grade, deposits are formed inside the converter. Since the ambient air of the converter is used as a coolant, the dust particles contained in the ambient air can deposit on surfaces of the converter's components, especially elements to be cooled. For surfaces to be cooled, for example of a heat sink or surfaces of lossy components, these deposits lead to overheating with subsequent failure. Deposits on insulating surfaces can bridge the electrical insulation and therefore endanger the function and safety of the converter.

[0003] Whether a converter put on the market is used according to its protection grade can no longer be checked by the manufacturer of this converter. Only when a converter has shut down owing to the occurrence of a fault and technicians open this converter in order to remedy the fault, can it be established whether this converter has been used according to its protection grade. If not, the components of the converter must be covered with deposits. Only then is it established that the cause of the shutdown of the converter is not due to design but due to use. When such a converter is incorporated in a production process, the entire production sometimes has to be interrupted because of the converter which has shut down, which entails significant consequential costs.

[0004] It is therefore an object of the invention to provide a method and a device for detecting a degree of contamination of an operational converter, so that the risk of a protective shutdown of the converter due to pollution can be detected even before an operational interruption.

[0005] This object is respectively achieved according to the invention by the features of claim 1 or 2 (method) and by the features of claim 8, 9 or 10 (device).

[0006] Since on the one hand an operating state of at least one of the converter's components which is exposed to the ambient air of the converter and on the other hand an operating state of this component in the unpolluted state are determined, the degree of pollution of the converter can be deduced by means of a comparison of these two operating states. The comparison value thus determined is a measure of the degree of pollution of the converter.

[0007] By means of the second method according to the invention, the degree of pollution of a converter is detected by means of determining a surface conductance of one of the converter's parts which is exposed to the ambient air of the converter and a predetermined limit value. With increasing pollution inside the converter, the surface conductance of one of the converter's parts which is exposed to the ambient air of the converter increases, and therefore the value of a leakage current increases.

[0008] In an advantageous embodiment of the method for detecting the degree of pollution, the recorded comparison values are stored. The progress of the pollution of a converter is therefore available for further evaluations. From this progress of the pollution of the converter, for example, a prognosis can be determined for the time of the protective shutdown of the converter. This means that the remaining operating hours of the converter can be displayed, so that a production process can be run down in a controlled way.

[0009] In a further advantageous method, a warning signal is generated when a predetermined comparison value is exceeded. In this way, the fact that unperturbed operation is at risk is displayed visually and/or acoustically.

[0010] In a further advantageous method a warning message, which reports an imminent protective shutdown of the converter, is generated when a second predetermined comparison value, which is greater than the first comparison value, is exceeded. This second comparison value is predetermined so that it is still possible to suspend the production process.

[0011] Components of the converter, whose power loss and/or temperature can be determined, are advantageously employed for diagnosing the pollution of the converter. The heat sink of the converter, on which the power semiconductors of the converter are fitted in a thermally conductive way, is particularly suitable for diagnosing the pollution of the converter. The temperature of the heat sink is recorded in order to monitor the power part of the converter. When a limit value is exceeded, the converter is shut down.

[0012] A first device according to the invention for detecting a degree of pollution of an operational converter has a thermal model for estimating a temperature of a heat sink of the converter, a temperature sensor for determining a heat sink temperature and an evaluation circuit, which is linked on the input side to the thermal model and the temperature sensor. In this way a degree of pollution of an operational converter can be diagnosed with few components, some of which are already present in the commercially available converter.

[0013] In a second device according to the invention for detecting a degree of pollution of an operational converter, a resistor bridge circuit is used which is linked on the input side to a voltage supply of the converter and whose resistors are dimensioned so that two diagonally opposite resistors change their resistance

by heating as a result of operation, whereas the other two maintain their resistance, and the output of which is linked to an evaluation circuit.

[0014] Advantageously, at least one resistor of the two resistors which change their resistance as a result of operation consists of a plurality of electrical resistors connected in series, which are arranged distributed in the converter. In this way, the pollution of the converter is detected not only at one predetermined position but inside the entire converter.

[0015] A third device according to the invention consists of the measurement of surface conductance. To this end this device comprises two conductor tracks extending close to each other, one of which is connected to a discharge resistor, in parallel with which a voltage follower is connected. The second conductor track is linked to a voltage supply of the converter. A measurement voltage is provided at the output of the voltage follower, the amplitude of which is proportional to a diagnosed degree of pollution of the converter.

[0016] With these methods and devices according to the invention, it is possible to reduce the number of failures due to a mode of operation of the converter which is not compliant with the protection grade, and the concomitant disadvantages such as costs and image loss.

[0017] To explain the invention further, reference will be made to the drawing in which several embodiments of the device according to the invention are illustrated schematically.

[0018] FIG. 1 shows an advantageous embodiment of a first device according to the invention,

[0019] FIG. 2 illustrates a further advantageous embodiment of the first device according to FIG 1,

[0020] FIG. 3 shows a second device according to the invention,

[0021] FIG. 4 illustrates a third device according to the invention,

[0022] FIG. 5 shows an embodiment of the measuring sensor of the device according to FIG 4.

[0023] An advantageous embodiment of a first device according to the invention is schematically represented in FIG 1. This device comprises a temperature model 2, a temperature sensor 4 and an evaluation circuit 6. The temperature sensor 4 is placed on the converter's component whose temperature is intended to be measured. This component is the heat sink of the converter, which comes directly in contact with the ambient air of the converter. The temperature model 2 is a temperature model which is known per se for the heat sink. With this temperature model, an expected heat sink temperature T_{KK} is determined as a function of an actual power loss P_V and an actual coolant temperature T_{umg}. The integration time constant corresponds to the thermal inertia, and the feedback coefficient corresponds to the inverse of the thermal resistance R_{th} of the heat sink. The power loss P_V is determined as in a conventional thermal model, for example for estimating a depletion layer temperature of a power semiconductor, from a load current value, an intermediate circuit voltage value, the phase control factor and a switching frequency. The coolant temperature T_{umg} is determined by means of a further temperature sensor which, for example, is arranged in the coolant flow. As a result, this temperature model 2 of the heat sink delivers an estimated heat sink temperature T_{KK} which the heat sink assumes by dissipating the power loss P_V, when it is not polluted.

[0024] The evaluation circuit 6 comprises a comparator 8 on the input side, downstream of which a memory 10 is connected. This memory 10 is connected on the output side to a comparison instrument 12, at the output of which a warning signal S_W is provided. Two limit values T_{KKeG1} and T_{KKeG2} for a comparison value T_{KKe} thus determined are furthermore fed to this comparison instrument 12. The memory 10 is needed only so that the time variation of the pollution can also be evaluated. Otherwise, the comparison value T_{KKe} thus determined may also be fed directly to the comparison instrument 12.

[0025] When the heat sink of the converter is polluted, the measured heat sink temperature T_{KKmes} is higher than the estimated heat sink temperature T_{KK} of the temperature model 2. A negative value is obtained as the comparison value T_{KKe}. The minus sign signifies that the heat sink of the power part of the converter is operating worse than intended. The value of this comparison value T_{KKe} indicates how much worse this heat sink is operating. Only when the value of this comparison value T_{KKe} thus determined is negative and its magnitude is equal to or greater than the first limit value T_{KKeG1} is a warning signal S_W generated, for example by driving a display. If the magnitude of the comparison value T_{KKe} increases owing to continuous pollution of the heat sink of the power part of the converter, so that it is equal to or greater than a second limit value T_{KKeG2} which is greater than the first limit value T_{KKeG1}, then a second warning signal S_W is generated. This warning signal S_W can be used in order to display that a degree of pollution is reached which makes it likely that a protective shutdown will be triggered within the foreseeable future, or an equipment malfunction will occur. By recording these individual comparison values as a function of time, for example, a residual operating time can be calculated. The residual operating time indicates that, under the prevailing operational conditions, the converter will shut down after the indicated time period has elapsed. An acoustic signal may be used in addition to the visual representation.

[0026] FIG 2 shows a further advantageous embodiment of the first device according to the invention. This embodiment differs from the embodiment according to FIG 1 in that the temperature model 2 is supplemented with an estimator for the thermal resistance R_{th} of the heat sink. This means that the value of the temperature difference T_{KKa} determined between the heat sink and the coolant is no longer fed directly to the inverse of the thermal resistance R_{th}, but instead to a multiplier 14 at the second input of which the inverse of the thermal resistance R_{th} is applied. An integrator 16, which is fed on the output side to the inverse of the thermal resistance R_{th}, is furthermore connected downstream of the comparator 8 of the evaluation circuit 6. The value which is obtained at the output of the integrator 16 is the efficiency η_{KK} of the heat sink, which is a direct measure of the effectiveness of the cooling system. An efficiency η_{KK} less than one means that there is pollution of the heat sink. The difference from $\eta_{KK} = 1$ indicates the degree of pollution of the heat sink of the converter. This value for the efficiency η_{KK} may be evaluated just like the temperature deviation T_{KKe} which is determined for the heat sink.

[0027] A second device according to the invention for detecting a degree of pollution of an operational converter is represented in more detail in FIG 3. This second device according to the invention consists of a resistor bridge circuit 18, which is linked on the input side to a voltage supply U of the converter. This resistor bridge circuit 18 comprises two resistors R_2 and R_3, which heat up as a result of operation and therefore increase their resistance, and two resistors R_1 and R_4 which do not change their resistance during operation of the converter. These resistors R_1 and R_4 either remain at ambient temperature or are made of a material having a temperature-independent resistance. If the resistances of these resistors R_1 to R_4 are selected so that a bridge diagonal voltage U_{diag} is exactly zero for unpolluted resistors R_1 to R_4 in the steady state, then this bridge diagonal voltage U_{diag} can be used directly as a measure of any pollution occurring in the operational converter.

[0028] In an advantageous embodiment of this device, the resistors R_2 and/or R_3 consist of a plurality of electrical resistors, which are arranged distributed inside the converter and are electrically connected in series. In this way, the pollution of the operational converter is determined not only at one predetermined position but in the entire converter.

[0029] A third device for determining a degree of pollution of an operational converter is illustrated in FIG 4. This device comprises a measuring instrument 20 for the surface conductance and a voltage follower 22. The measuring instrument 20 comprises a discharge resistor 24 and a measuring sensor 26. The measuring sensor 26 used consists of two conductor tracks 28, 30 extending close to each other, for example, which are routed over those circuit board regions of the converter in which the greatest pollution is expected during operation of the converter. This design of this measuring sensor 26 is represented in more detail in FIG 5. A supply voltage U of the converter is applied to the input terminals 32 and 34 of the measuring instrument 20. The input terminal 32 is connected electrically conductively to the conductor track 28 of the measuring sensor 26, whereas the conductor track 30 is connected to one pole of the discharge resistor 24. The second input terminal 34 of the measuring instrument 20 is linked to the free pole of the discharge resistor 24. So that a leakage current proportional to the pollution of the converter can flow, these two conductor tracks 28 and 30 are free of solder stop resist. A voltage proportional to this is then set up across the discharge resistor 24. This voltage is smoothed by means of a capacitor 36. The voltage follower 22, which is used as an impedance converter, generates from this smoothed voltage a measurement voltage U_{mes} which is proportional to the pollution of the operational converter. Instead of the two conductor tracks 28 and 30 extending close to each other, it is alternatively possible to use solder eyelets which are provided at regular intervals.

[0030] With these devices, whose components may be integrated in a converter or sometimes already belong to the converter, the pollution of the converter can be diagnosed straightforwardly during its operation. The risk of equipment malfunctions or failures due to progressive pollution can therefore be detected already before an operational interruption takes place. This reduces the number of failures and the concomitant disadvantages such as costs and image loss.